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ABSTRACT

This article is based on two main theses: a) qualitative improvements in education will not come about as a result of rhetoric or superficial proposals for solutions made by the so-called new breed or educators, but rather as a result of a deeper understanding of the teaching-learning process and the development and use of new and better principles of educational design; b) theoretical bases for qualitative improvements in educational design already exist and should be used more widely by educators. The paper is subdivided as follows: a) a brief review of the recent history of educational psychology to provide a perspective for later remarks; b) a summary of some of the more immediately relevant portions of a new theory of structural learning; c) a discussion of how the theory might be extended to provide a basis for conceptualizing the teaching-learning process, involving realistic content, and optimizing instruction; d) a taxonomy based on this conceptualization for classifying various types of instruction ranging from the open classroom to more classic examples of classroom management. (Author/JA)

STRUCTURAL LEARNING AND THE OPTIMIZATION OF OPEN EDUCATION

by

Joseph M. Scandura
MERG and University of Pennsylvania

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Philadelphia, Pennsylvania

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This article is based on two main theses: One, qualitative improvements in education will not come about as a result of rhetoric or superficial proposals for solution made by the so-called "new breed" of educator, but rather as a result of a deeper understanding of the teaching-learning process, and the development and use of new and better principles of educational design. Two, theoretical bases for qualitative improvements in educational design already exist and should be used more widely by educators.

More specifically, the paper is subdivided as follows: (1) a brief review of the recent history of educational psychology to provide a perspective for later remarks, (2) a summary of some of the more immediately relevant portions of a new theory of structural learning (Scandura, 1971, 1973), (3) a discussion of how the theory might be extended so as to provide a basis for conceptualizing the teaching-learning process, involving realistic content, and including the optimization of instruction, (4) a taxonomy based on this conceptualization for classifying various types of instruction ranging from the open classroom to more classic examples of classroom management.

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Background

For many years, educational psychology and the application of psychology to education were practically synonymous. Courses in educational psychology consisted of frequently watered down versions of principles adapted from the various sub-specialties of academic psychology. Traditional learning theory rightfully played a predominant role. This circumstance was not so much a result of choice, but of necessity. Indeed, many learning theorists of past decades have realized the inadequacy of their theories with regard to human application. Some, like the late Kenneth Spence, emphasized this point whenever the opportunity arose. Educational psychologists, unfortunately, were only able to choose from among the various competing theories, selecting this one or that, without themselves having anything better to propose.

But times do change. During and after World War II, the urgent need to train personnel to perform complex tasks, and to do so quickly, resulted in the recruitment and involvement of psychologists in designing efficient systems of training. This work continued through the 1950's, and subsequent to increased support for educational research, the movement expanded and was generalized to school learning. Progress during the 1960's was real, and although most of the really complex problems remained unsolved, educational technology began to evolve as a discipline in its own right. It became increasingly clear to all involved that psychology did not have ready made answers which needed only to be applied. Furthermore, the very directions of the research in academic psychology made it unlikely that much of real value would soon be forthcoming.

During this period of the 1960's, "operational objectives," "prerequisites," "hierarchies," "mastery (criterion referenced) testing," and the like became frequent topics of discussion. Such concepts and techniques have been acclaimed by many educators, and widely used in curriculum construction. They have, on the other hand, been the subject of a good deal of criticism. The most valuable educational objectives cannot be operationalized, some have said. Others point out that the approach leads to fragmented curricula. So goes the story.

It is my contention, based on research on structural learning that is currently underway both in our laboratory, and in others, that these criticisms, while they may be partially justifiable, are not inherent in structural approaches to education. We may reasonably expect that present limitations may be overcome in the relatively near future.

Unfortunately, the activism of the late 1960's resulted in a shift of interest from educational technology to the more social and "humanistic" aspects of educational reform. The recommendations made during this period ranged from well-intended (and valid, but rather obvious) warnings that education cannot take place in a social vacuum to high sounding rhetoric and simplistic solutions that have no more scientific validity than alchemy or witchcraft. The torch was passed from serious scientists to so-called experts like Charles Silberman, author of "Crisis in the Classroom," and more recently Christopher Jencks with "Inequality." These and other authors of the same ilk have dramatically pointed out shortcomings of our schools, something which unfortunately is all too easy, but have suggested nothing solid to take their place. Some of Silberman's criticisms of technology-based school curricula,

for example, were based on an inadequate understanding of the basic philosophy of the approach, a potential that goes far beyond the limited role he saw for it, and a general lack of expertise concerning the teaching-learning process. Jencks' work can be similarly criticized beyond the obvious sensationalism that went into its promotion. (The author's written reaction may be obtained upon request.) For present purposes, it will suffice to say that Jencks is warranted in criticizing such panaceas as the "open classroom" and "vouchers," which have been proposed by various socio-educational reformers (including himself). His basic conclusion concerning the inability of schools to overcome inequities in educational opportunity, however, cannot be justified for two reasons. First, Jencks seems unaware of fundamental limitations in his research methods which makes this basic conclusion unsupportable. Second, he appears totally ignorant of recent basic research on complex human learning which blows to pieces his fundamental thesis.

Largely unnoticed during this period were a number of important developments in such related, yet diverse, fields as formal linguistics, artificial intelligence, logic and mathematical foundations, information processing psychology, rule learning, and some fundamental work in educational design - the confluence of which I have called structural learning (cf. Scandura, 1971, 1973). Fortunately for the future, the relevance to educational design and curriculum development of recent work in structural learning is being increasingly well-recognized. Prototype educational products, based directly on the theoretical ideas which have evolved, have been developed and tested for effectiveness, sometimes with startling results (cf. Scandura, 1972a and b). Given a child who knows the basic number facts, for example, it has been

possible to teach him (or her) to add numerals of arbitrary size in a total of about ten to twelve hours of instruction. Subtraction takes, on the average, only half as long. And this with materials which have not yet been refined!

Implications of this work also extend to such "non-structured" areas as critical reading based on logical inference. Instructional and test materials have been developed which can be used not only to pinpoint the relevant capabilities had by given individual students, but also to provide exactly that instruction the individual students need in order to overcome these inadequacies. And, the material works; we have solid data to support this view (Lowerre & Scandura, 1973, in press). In another study (Ehrenpreis & Scandura, 1972), the potential to transfer was consciously and systematically built directly into a mathematics curriculum for teachers. Our data showed unequivocally that this too works.

More importantly for the future of education, although movement in this direction is not as rapid as might be desired, I detect increasing signs of dissatisfaction with the "activists" prescription for education, and feel that we can look forward with confidence to the eventual return to more reasoned and careful planning in education.

The Theory of Structural Learning

Let us now look at some of the more immediately relevant portions of the theory of structural learning. As those of you who have followed my research know, over the past decade this research has gone through several phases. My initial efforts, centering about my dissertation work at Syracuse, had the rather optimistic goal of understanding the teaching-learning process in its

full complexity. I need not tell you that while some interesting ideas grew out of this work, my initial efforts were something less than a complete success.

The second phase was spent trying to get a better handle on the problems involved, including the development of suitable research paradigms. This research consisted of a large number of individual studies ranging over a wide variety of phenomena involving complex human learning. A major theme of this research was that rules provide a more appropriate basis for analyzing complex human learning than do associations. Rather than viewing rules as complex networks of associations, it was proposed that associations might better be thought of as special degenerate cases of rules. The full implications of this idea only became clear to me during the last few years.

The fundamental notion of representing knowledge in terms of rules (procedures), together with the introduction of just a few other equally basic assumptions, have provided the basis for a new comprehensive theory of structural learning. This theory consists of three distinct and easily identifiable, but complementary, levels of theorizing, each with its own type of empiricism. The first level of the theory is concerned with competence - with how to account for the potentially observable behavior of interest to an observer. In this theory, competence consists of a finite set of rules together with laws governing the way in which these rules may interact in account for behavior.

What is new in the theory is the idea of allowing rules to operate in a higher order fashion, that is, to operate on, and to generate new rules. This relatively simple conceptual change not only provides a great increase in explanatory power, but is consistent with how human beings use the knowledge

they have. Thus, individuals do not have to be taught explicitly every rule that might be desired. Much of their knowledge is latent in the sense that it can be derived at will when needed from other information which is explicitly available.

The second level of the theory is obtained by adding more structure to the first and deals with the behavior of humans under certain idealized conditions. This idealized theory is concerned with questions of performance, learning, motivation, and even perception, in situations where the subject is not hampered by memory or his limited capacity for processing information. More particularly, this level of theory does two things.

First, it provides a basis for operationally defining the knowledge had by individual subjects. That is, the behavior potential of individuals is determined via a finite testing procedure which essentially "measures" each individual's knowledge relative to the rules in a given competence theory. The idea is not unlike diagnostic testing except that the approach is theoretically more rigorous and empirically more precise (cf. Scandura & Durnin, 1973, in press; Durnin & Scandura, 1973, in press).

Second, the theory deals with the question of how and why available knowledge is put to use and how it is acquired in the first place. All learning is viewed as a problem solving process (Scandura, 1971). If the subject does not have a rule explicitly available for achieving a given goal, then control is assumed to automatically move to the higher order goal of deriving a rule which will satisfy the original goal. Once such a higher order goal has been satisfied, control is assumed to revert back to the original goal so that the newly derived rule can be applied and the problem solved.

The unrestricted third level of the theory deals also with memory and the limited capacity of subjects to process information. The overall theory was first outlined in published form in Scandura (1971) and has been refined and detailed, with a substantial body of empirical research supporting the theory, in a forthcoming book (Scandura, 1973.)

Although the main effort to date has been on theory development, substantial beginnings also have been made in developing practical implications of this work for curriculum development and instructional planning as was suggested above. New approaches to diagnostic testing have been developed together with various kinds of prototype curricula.

During the past four years, an increasing amount of empirical support for the theory has been obtained. Specifically, we have found among other things that: (1) It is both theoretically possible and practicable to determine the knowledge had by individual students. This includes higher order capabilities. (2) The problem solving mechanism proposed does provide an adequate basis for explaining problem solving performance and learning under the idealized conditions tested. (3) The higher order rules method of analysis apparently can be applied to even relatively complex mathematical subject matters such as geometry constructions with straightedge and compass. (4) The method is robust, one can "cut corners" and still use the method successfully in broad based curriculum construction.

3. The Optimization of Instruction

Although substantive empirical work is still in the planning stages, it is fairly apparent at a conceptual level how the Structural Learning Theory provides a basis for conceptualizing the teaching-learning process. In outline form the idea is as follows. The learner has certain knowledge (rule sets) at his command on entering into the teaching situation. Additional learning takes place by interacting with the teaching environment. What is learned at each stage depends both on what is presented to the learner and what he knows. The changes from stage to stage are cumulative.

In order to talk about the optimization of instruction, two additional ideas must be considered. First, we must be able to characterize the educational objectives to be achieved, and we must assign values to these objectives. For present purposes, let us think of the objectives as behavioral objectives with the proviso that objectives corresponding to higher order rules are included. Clearly, individual objectives may vary in importance depending upon what the teacher or curriculum constructor values most. Weights are assigned to the various objectives to reflect these values.

The second idea concerns the various costs of instruction. Time required for instruction would seem to provide a natural measure.

The optimization of instruction, then, consists of finding an optimal trade-off between the sum of the values of the objectives to be achieved and the total time required for instruction. It will frequently be the case, for example, that the instructional costs involved in achieving a highly valued objective are apt to be relatively high. Optimization involves balancing gains against costs - a type of cost-benefit analysis.

Obviously, much more could be said about this type of analysis, but the above will suffice for our purposes.

3. <u>A Scheme for Classifying Types of Instruction</u>

Let us now consider how the values assigned to the possible objectives associated with a given curriculum, and the costs assigned to instruction, provide a simple basis both for classifying different types of curricula and for specifying the kinds of conditions under which each is to be preferred - that is, how they provide a basis for tailoring curricula to needs and circumstances.

Within this framework, a basic problem of curriculum planning is to assign values to the various possible objectives, and to assign costs to various kinds of instruction. Insofar as assigning values to objectives is concerned, the possibilities range from giving high value to relatively few objectives, with low value to the others, to moderate value over a broad range of objectives. At the one extreme, for example, high value might be placed on computational skill in arithmetic, with little concern for meaning, while at the other extreme, a broad range of arithmetic abilities might be given equal weight. In the figure below, at the risk of oversimplification, the possible assignments of values between these extremes is represented by a single dimension.

Instructional time costs are similarly represented. In this case, the dimension ranges from high costs for all but a small range of kinds of instruction to more evenly moderate costs for a broader range of instructional forms. Thus, for example, at one extreme, circumstances might require an expository form of instruction because of the relatively high costs of other forms. At the other extreme, a broad range of possibilities might be equally viable. (We note parenthetically that these dimensions would lend themselves quite naturally to information-theoretic measures.)

INSERT FIGURE 1 ABOUT HERE

A number of typical curriculum forms are plotted on the grid. Although one should not take the exact placement of these types too seriously, their classification does show how arbitrary curriculum forms may be viewed in these terms. For example, the Summerhill school, which is well-known for its broad-based, permissive atmosphere, is placed at the lower right. In contrast, military training, with its high premium on the efficient acquisition of certain skills, is placed in the upper left.

In conclusion, I would like to emphasize two points which are central to my main thesis. One, the efficiency of various types of curricula depends on the values assigned to possible educational objectives and the costs (or availability) of various kinds of instruction. The open classroom, for example, is a suitable form of instruction, but only where there is a reasonably broad choice of objectives and largely equivalent costs for various forms of instruction. Two, any type of curriculum, including the open classroom, may be conceptualized in terms of an underlying theory of structural learning.

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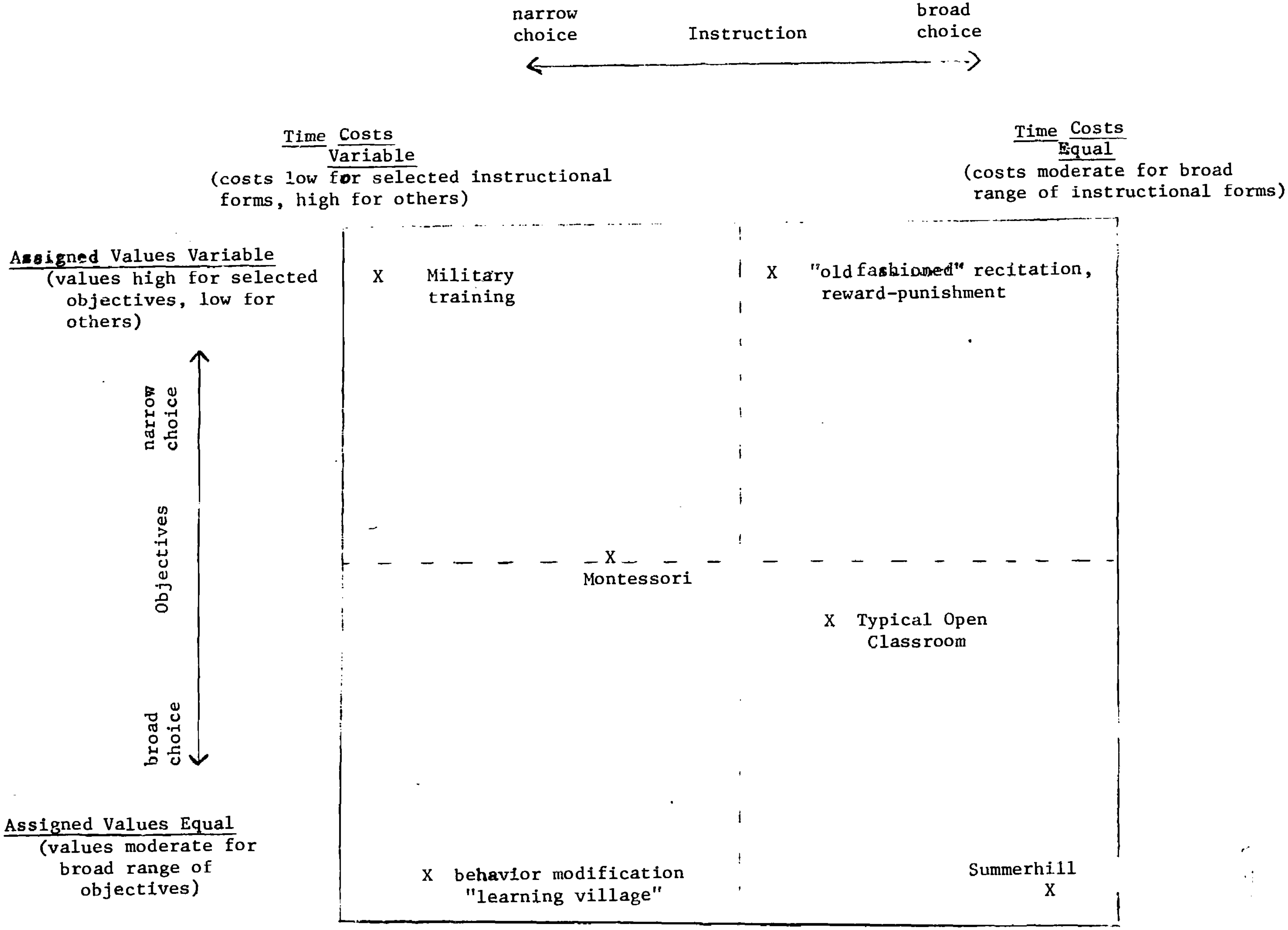
narrow choice
Instruction
broad choice
Time Costs Variable
(costs low for selected instructional forms, high for others)
Time Costs Equal
(costs moderate for broad range of instructional forms)
Assigned Values Variable
(values high for selected objectives, low for others)
narrow choice
Objectives
broad choice
Assigned Values Equal
(values moderate for broad range of objectives)
X Military training
X "old fashioned" recitation, reward-punishment
X Montessori
X Typical Open Classroom
X behavior modification "learning village"
Summerhill X

Figure 1

MERG

(Mathematics Education Research Group)

University of Pennsylvania

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